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EP-A- 0 274 608
DE-A- 3 722 102
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APATITE PACKING FOR LIQUID CHROMATOGRAPHY AND PROCESS FOR PRODUCING THE SAME

FIELD OF THE INVENTION

The present invention relates to a packing for liquid chromatography, and more specifically, a packing for liquid chromatography for separation and purification of proteins, enzymes, nucleic acids, etc. and a process for producing the same.

BACKGROUND OF THE INVENTION

Generally employed packing material for liquid chromatography include silica gel, chemically modified silica gel, synthetic high polymer gels, naturally ocurring high polymer gels, carbon gel, and the like.

Hydroxyapatite represented by formula $Ca_{10}(PO_4)_6(OH)_2$ has been used as a packing for liquid chromatography for separating high molecular weight biocompounds, such as proteins, nucleic acids, sugars, glycosides, etc. because of its excellent biocompatibility.

The hydroxyapatite packing shows both cation exchanging ability and anion exchanging ability to proteins, etc., while exhibiting high ability in separation of glycosides in the normal phase mode using acetonitrile and water as a eluent. Owing to such characteristics, a single column packed with hydroxyapatite can be applied to separation of a variety of substances. Further, since the desired substance can be separated under mild elution conditions, the sample under chromatography is protected from deactivation. Furthermore, the column has a high recovery. Therefore, with developments in the biological industry, hydroxyapatite has been regarded as one of the most promising packings for chromatography. That is, hydroxyapatite is the only one of the apatite compound which has hitherto been used as a packing for liquid chromatography, as described in Journal of Liquid Chromatography, vol. 9(16), pages 3543 to 3557 (1986).

However, the hydroxyapatite packing is poor in resistance to dissolution in acidic solutions, sometimes failing to fulfil its function. That is, when an acidic mobile phase is passed through a column packed with hydroxyapatite for a long period of time, crystals of hydroxrapatite are dissolved out and fine crystals released from the surface of packing particles and obstruct the passage of the mobile phase, eventually rendering the packing useless. Therefore, the conventional hydroxyapatite packing is not suitable for separation processes under acidic conditions. Particularly at a pH of 5.5 or less, such packing cannot be used continuously, and thus the range of substances which can be separated using hydroxyapatite is naturally limited.

Apatite containing at least one of tin and lead has been reported, as described in Transaciton of 39th Colloid and Interface Chemistry Symposium, pages 342 to 343, held on October 6 to 8, 1986 at Ibaraki, Japan. However, its application to chromatography has not yet been established.

SUMMARY OF THE INVENTION

An object of this invention is to provide a packing for liquid chromatography having improved acid resistance while maintaining the advantages of conventional hydroxyapatite packings, and which exhibits high performance for separating a wide range of substances.

Other objects and effects of the present invention will be apparent from the following description.

The above objects of the present invention have been attained by an apatite packing for chromatography comprising particles having at least on the surface thereof apatite containing at least one of tin and lead.

BRIEF DESCRIPTION OF DRAWING

Fig. 1A is a chromatogram obtained in Example 1 and Fig. 1B is a chromatogram obtained in Example 2.

Fig. 2A is a chromatogram obtained in Example 3 and Fig. 2B is a chromatogram obtained in Example 4.

Fig 3A is a chromatogram obtained in Comparative Example 1 and Fig. 3B is a chromatogram obtained in Comparative Example 2.

DETAILED DESCRIPTION OF THE INVENTION

The apatite containing at least one of tin and lead used in the present invention can be produced by a synthetic method including a wet method and a dry method or an ion exchanging method.

When the apatite containing at least one of tin and lead used in the present invention is produced by the wet method, (1) phosphoric acid or a water

soluble phosphate, (2) a calcium compound and (3) a water-soluble lead compound and/or a water-soluble tin compound are reacted in an aqueous solution in a suitable amount proportion. When the dry method is employed, (1) a phosphoric acid compound, (2) a calcium compound and (3) a lead compound and/or a tin compound are reacted at a high temperature in a suitable proportion.

The wet method can be conducted according, e.g., to Ann. Chem. (Paris), vol. 7, 808 to 832 (1952); J. Res. Nat. Bur. Stand., vol. 72A, 773 (1968); and Archs. Oral. Biol., vol. 23, 329 to 336 (1978). The dry method can be conducted according, e.g., to Arch. Intern. Physiol. Biochim., vol.72, 337 (1964); Chem. Abstr., vol. 60, 15418a (1964); and Studii Cercetari Chim., col. 13, 157 (1962).

In the case of the ion exchanging method, hydroxyapatite particles capable of being used as a packing for chromatography are immersed in an aqueous solution containing a water-soluble lead compound and/or a water-soluble tin compound.

Examples of the water-soluble lead compound include lead chloride, lead fluoride, etc. Examples of the water-soluble tin compound include tin chloride, tin fluoride, etc.

Examples of the embodiments of the present invention include the following:

(1) a packing comprising the apatite containing at least one of tin and lead throughout the individual particles, (2) a packing comprising apatite particles of which surface is the apatite containing at least one of tin and lead, and (3) a packing comprising inert carrier particles coated with the apatite containing at least one of tin and lead.

The term "apatite" used herein means not only hydroxyapatite but also other apatite compounds including chlorinated apatite and fuorinated apatite.

In the above embodiment (1), the whole of the individual particles is formed of the apatite containing at least one of tin and lead and preferably has a porosity of from 0 to 50% and a specific surface area of from about 0.01 to 20 m^2/g. The porosity can be controlled by changing the calcining temperature or the density of the prticle forming material.

In the above embodiments (2) and (3), the thickness of the surface layer of apatite containing at least one of tin and lead is preferably about 1 μm or more. The porosity and the specific surface area of the packing are preferably from 0 to 50% and from about 0.01 to 20 m^2/g, respectively.

The above embodiment (1) in which the whole of the individual particles is formed of the apatite containing at least one of tin and lead can be prepared by heat-treating an agglomerate of the particles of the apatite containing at least one of tin and lead prepared by the above methods at a suitable temperature.

The above embodiment (2) in which the surface of apatite particles is the apatite containing at least one of tin and lead can be prepared by immersing and stirring an agglomerate of apatite particles in an aqueous solution containing a water-soluble lead compound and/or a water soluble tin compound, and then drying and heat-treating at a suitable temperature.

The immersing and stirring is generally carried out under acidic conditions at a temperature of from 5 to 90° C for from 0.5 to 10 hours.

The above embodiment (3) in which inert carrier particles such as alumina are coated with the apatite containing at least one of tin and lead can be prepared by sputtering or the like methods, as described.

The packing particles for liquid chromatography of the present invention are not particularly limited in size, shape, porosity, etc. However, performances such as separating ability can be assured by following a general particle design for packings for liquid chromatography. For example, the packing preferably has an average particle diameter of from about 1 to 100 μm, more particularly from about 10 to 100 μm for industrial use and from about 1 to 10 μm for use in analyses. If the average particle size is less than about 1 μm, the pressure drop on passing a liquid sample through a column packed with the packing becomes too large. If it exceeds about 100 μm, the surface area of the packing per unit volume is too small to assure separating ability. The packing preferably has a shape near to a spherical form in order to obtain stable separation characteristics while preventing cracks or cutouts, although particles having a macadamized form may be used. The porosity is preferably high in view of the load of the samples, but non-porous packing may be used, for example, for analytical purposes. The specific surface area is preferably from about 0.01 to 20 m^2/g, although it may be varied depending on the form of the packing particles.

The packing of the present invention can be used for a method for liquid chromatography by sequentially (a) packing a column with the packing of the present invention, (b) contacting the packing with a sample comprising at least one solute, and (c) contacting the packing with a liquid mobile phase to separate the solute by elution.

Upon carrying out the method for liquid chromatography, the preferred eluents are as follows: In an ion exchanging mode, (1) a sodium phosphate buffer (pH 5 to 9), (2) a potassium phosphate buffer, (3) a mixture of a sodium chloride solution and various buffers (e.g., tris buffer, pipes buffer, etc.) and (4) a mixture of a potassium chloride solution and varous buffers (e.g., tris buffer, pipes buffer, etc.). In the cases of (1) and (2), a

gradient elution at a concentration of from 10-100 mM to 1 M is preferred. In a normal mode, an isocratactic elution with the acetonitrile/water ratio of from about 7/3 to 9/1, and a gradient elution while increasing the water concentration are preferred.

The packing for liquid chromatography according to the present invention can be suitably applied to separation of solutes such as proteins (e.g., monoclonal antibody and fibronectin), enzymes (e.g., ligase and protease) , nucleic acids, (e.g., nucleotide, oligonucleotide, DNA and RNA), glycosides (ginsenoside, steviside, rebaudioside and saponin), and so on and exhibits stable separation performance even in an acidic solution, e.g., phosphoric acid, hydrochloric acid, etc. having a pH of 3 or more.

The present invention is now illustrated in greater detail with reference to the following Example and Comparative Example, but the present invention is not to be construed as being limited thereto.

Unless otherwise indicated, all parts, percents, ratios and the like are by weight.

EXAMPLE 1

(1) Preparation of Sn-containing apatite

2.26 g of stannous chloride and 6.28 g of stannous fluoride were dissolved in 2 ℓ of water. 12 g of an agglomerate of spherical hydroxyapatite particles was added to the solution obtained so as to be reacted for 2 hours while adjusting the pH to 3.0. The resulting reaction product was filtered and dried to obtain a powderous packing according to the present invention. The formation of Sn-containing apatite by the above procedures was confirmed by X-ray diffractiometry, atomic-absorption spectroscopy, etc.

(2) Chromatography

The thus-obtained packing was filled in a stainless steel column having a diameter of 7.5 mm and a height of 100 mm. A sample solution containing a phosphoric acid buffer solution (pH = 6.8) having dissolved therein 10 μg/μℓ of bovine serum albumin, 1.25 μg/μℓ of lysozyme, and 5 μg/μℓ of cytochrome C was passed through the column.

Elution was made by a linear gradient method at a flow rate of 1.0 mℓ/min for 30 minutes by using a sodium phosphate buffer (pH = 6.8) having a concentration of from 0.01 to 0.4M as an elvent so as to obtain a chromatogram shown in Fig. 1A.

In Figs. 1A, 1B, 2A, 2B, 3A and 3B, peak 1 is the peak of bovine serum albumin, peak 2 is the peak of lysozyme, and peak 3 is the peak of cytochrome C.

EXAMPLE 2

After passing through a column filled with the packing prepared in Example 1 a sodium phosphate buffer having a pH of 4.0 and a concentration of 0.4M at a flow rate of 1.0 mℓ/min for 5 hours, the sample solution used in item (2) of Example 1 was separated in the same manner as in item (2) of Example 1 so as to obtain a chromatogram shown in Fig. 1B.

As is clear from Figs. 1A and 1B, when the Sn-containing apatite packing according to the present invention was used, no peak splitting occured even after a 0.4M sodium phosphate buffer having a pH of 4.0 was passed for 5 hours. Thus, high separation performance was attained.

EXAMPLE 3

(1) Preparation of Pb-containing apatite

27.8 g of lead chloride was dissolved in 2 ℓ of water. 15 g of an agglomerate of spherical hydroxyapatite particles was added to the solution obtained so as to be reacted for 2 hours while adjusting the pH to 3.0. The resulting reaction product was filtered and dried to obtain a powderous packing according to the present invention. The formation of Pb-containing apatite by the above procedures was confirmed by X-ray diffractiometry, atomic-absorption spectroscopy, etc.

(2) Chromatography

The thus-obtained packing was filled in a stainless steel column having a diameter of 7.5 mm and a height of 100 mm. The sample solution used in item (2) of Example 1 was separated in the same manner as in item (2) of Example 1 so as to obtain a chromatogram shown in Fig. 2A.

EXAMPLE 4

After passing through a column filled with the

packing prepared in Example 3 a sodium phosphate buffer having a pH of 4.0 and a concentration of 0.4M at a flow rate of 1.0 mℓ/min for 5 hours; the sample solution used in item (2) of Example 1 was separated in the same manner as in item (2) of Example 1 so as to obtain a chromatogram shown in Fig. 2B.

As is clear from Figs. 2A and 2B, when the Pb-containing apatite packing according to the present invention was used, no peak splitting occured even after a 0.4M sodium phosphate buffer having a pH of 4.0 was passed for 5 hours. Thus, high separation performance was attained.

COMPARATIVE EXAMPLE 1

The same procedures as in item (2) of Example 1 were repeated except that a conventional hydroxyapatite packing was used instead of the packing of the present invention used in Example 1 so as to obtain a chromatogram shown in Fig. 3A.

COMPARATIVE EXAMPLE 2

After passing through the column a 0.4M sodium phosphate buffer having a pH of 4.0 for 1 hours, the same procedures as in Comparative Example 1 were repeated so as to obtain a chromatogram shown in Fig. 3B.

As is clear from Figs. 3A and 3B, when the conventional hydroxyapatite packing was used, peak splitting caused by the deterioration of the column occured after a 0.4M sodium phosphate buffer having a pH of 4.0 was passed for 1 hours.

As described above, the packing for liquid chromatography according to the present invention has excellent acid resistance while maintaining high separation performance of conventional hydroxyapatite packings, and does not deteriorate even after passing an acidic solution. Therefore, the packing of the present invention can be used stably for separating various compounds, particularly proteins, enzymes, nucleic acids, sugar, glycosides, etc., even in an acidic region for a long period of time.

While the invention has been described in detail and with reference to specific embodiments thereof, it will be apparent to one skilled in the art that various changes and modifications can be made therein without departing from the spirit and scope thereof.

Claims

1. An apatite packing for chromatography comprising particles having at least on the surface thereof apatite containing at least one of tin and lead.

2. An apatite packing for liquid chromatography as claimed in claim 1, wherein the average diameter of said packing is from 1 to 100 μm.

3. An apatite packing for liquid chromatography as claimed in claim 1, wherein the whole of the particles of said packing is formed of said apatite containing at least one of tin and lead.

4. An apatite packing for liquid chromatography as claimed in claim 1, wherein said packing comprises apatite particles having on the surface thereof said apatite containing at least one of tin and lead.

5. An apatite packing for liquid chromatography as claimed in claim 1, wherein said packing comprises an inert carrier particles coated with said apatite containing at least one of tin and lead.

6. A method for producing an apatite packing for liquid chromatography comprising the step of: immersing and stirring agglomerate of apatite particles in an aqueous solution containing at least one of a stannous ion and a lead ion so as to convert said apatite particles into apatite containing at least one of tin and lead.

7. A method for producing an apatite packing for liquid chromatography as claimed in claim 6, wherein said immersing and stirring step were carried out at a temperature of from 0.5 to 90° C for from 0.5 to 10 hours.

8. A method for liquid chromatography comprising the steps of:

(a) packing a column with an apatite packing comprising apatite containing at least one of tin and lead;

(b} contacting said packing with a sample comprising at least one solute;

(c) contacting said packing with a liquid mobile phase to separate said solute by elution.

9. A method for liquid chromatography as claimed in claim 8, wherein said solute is selected from a protein, an enzyme, a nucleic acid and a glycoside.

10. A method for liquid chromatography as claimed in claim 8, wherein said mehtod for liquid chromatography is conducted at a pH of 3 or more.

Fig. 1A

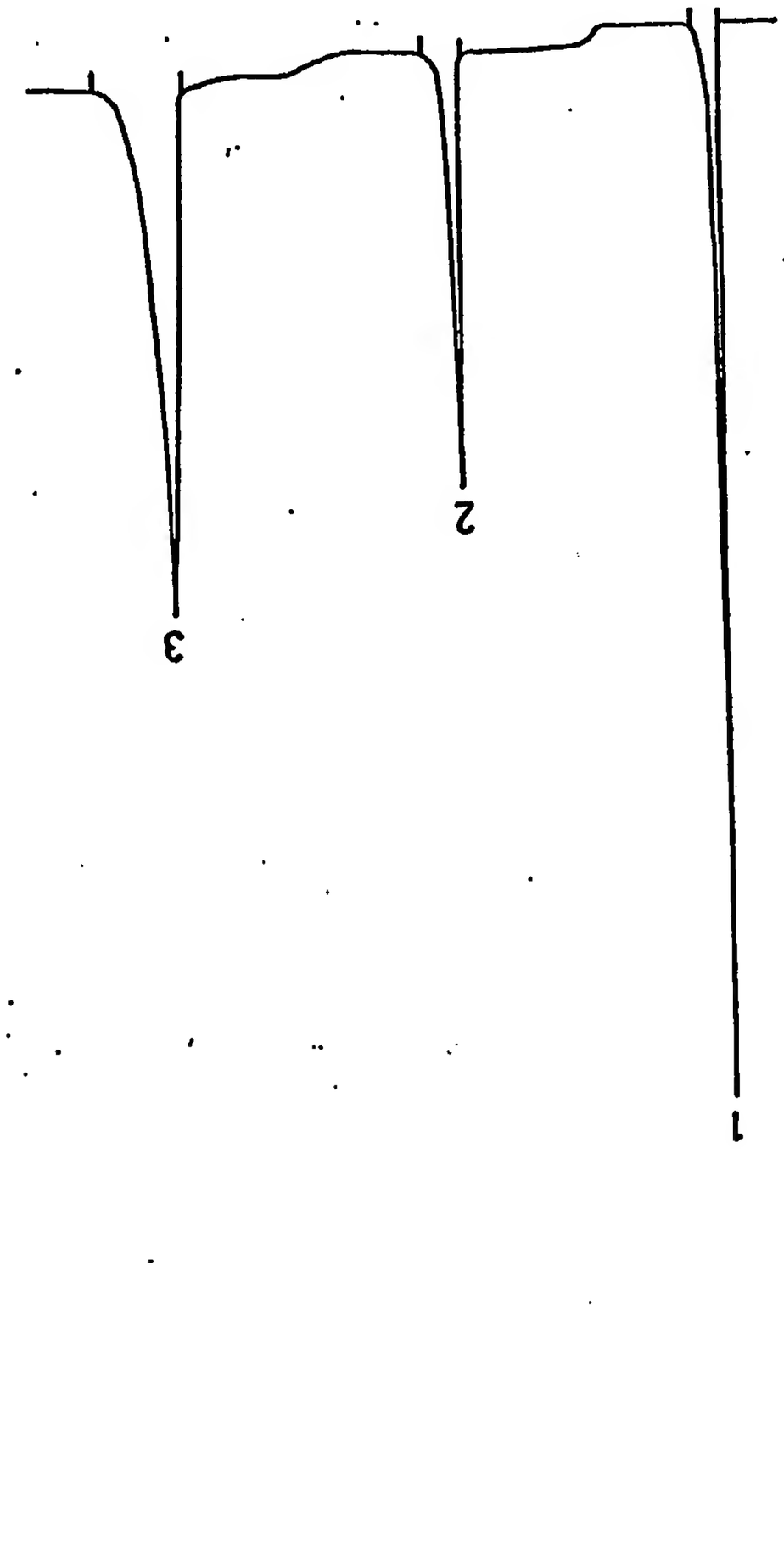


Fig. 1B

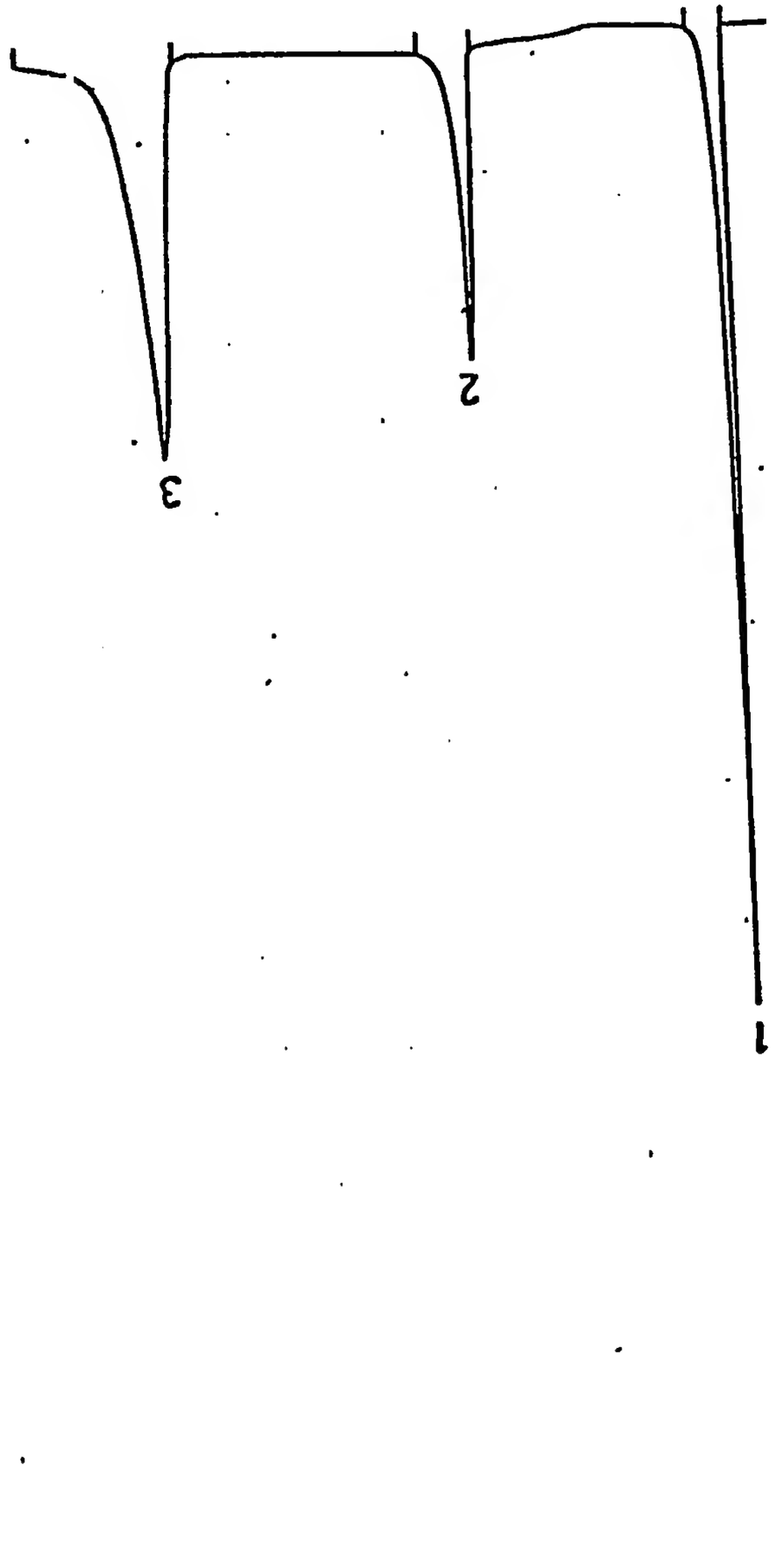


Fig. 2A

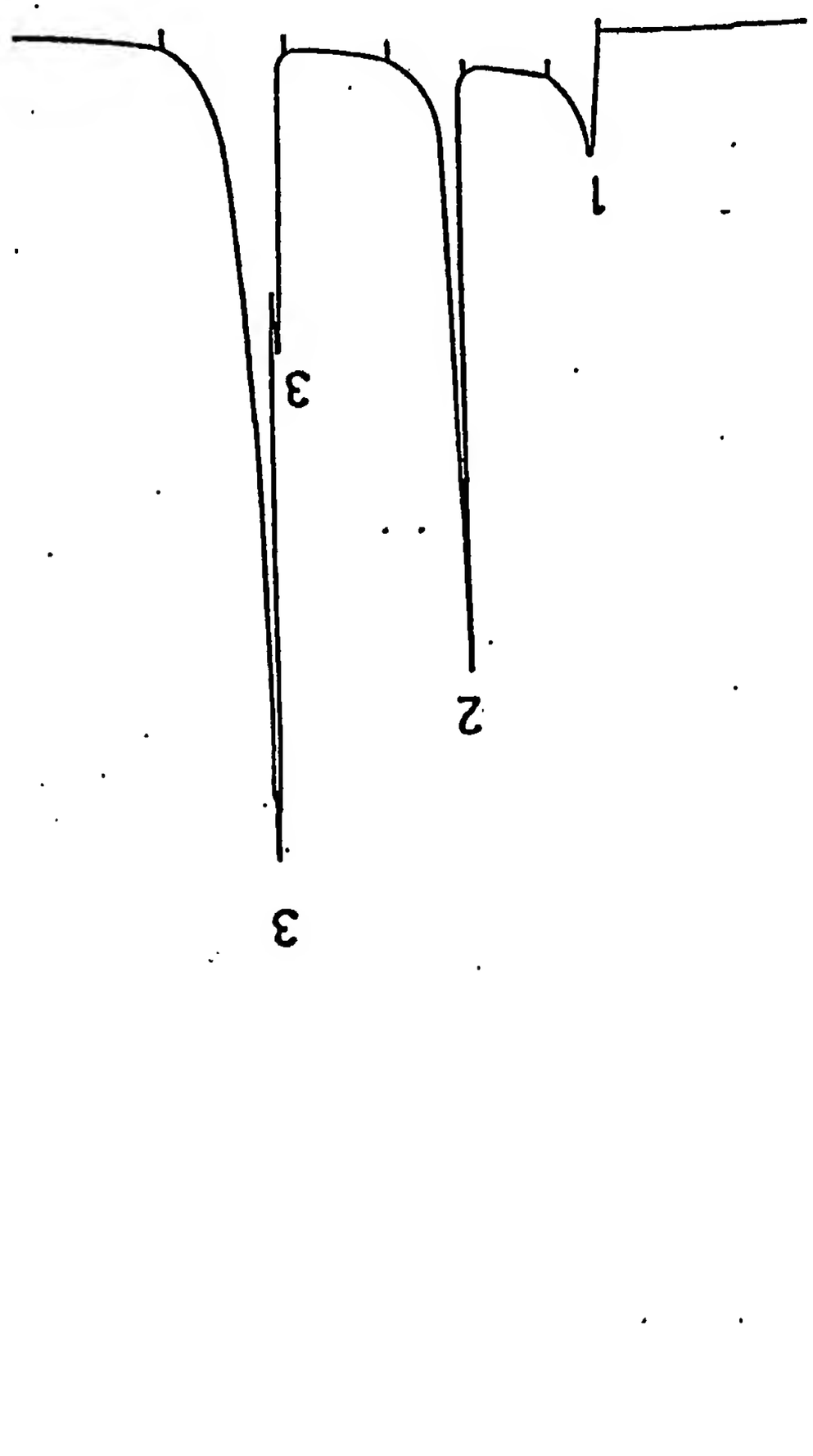
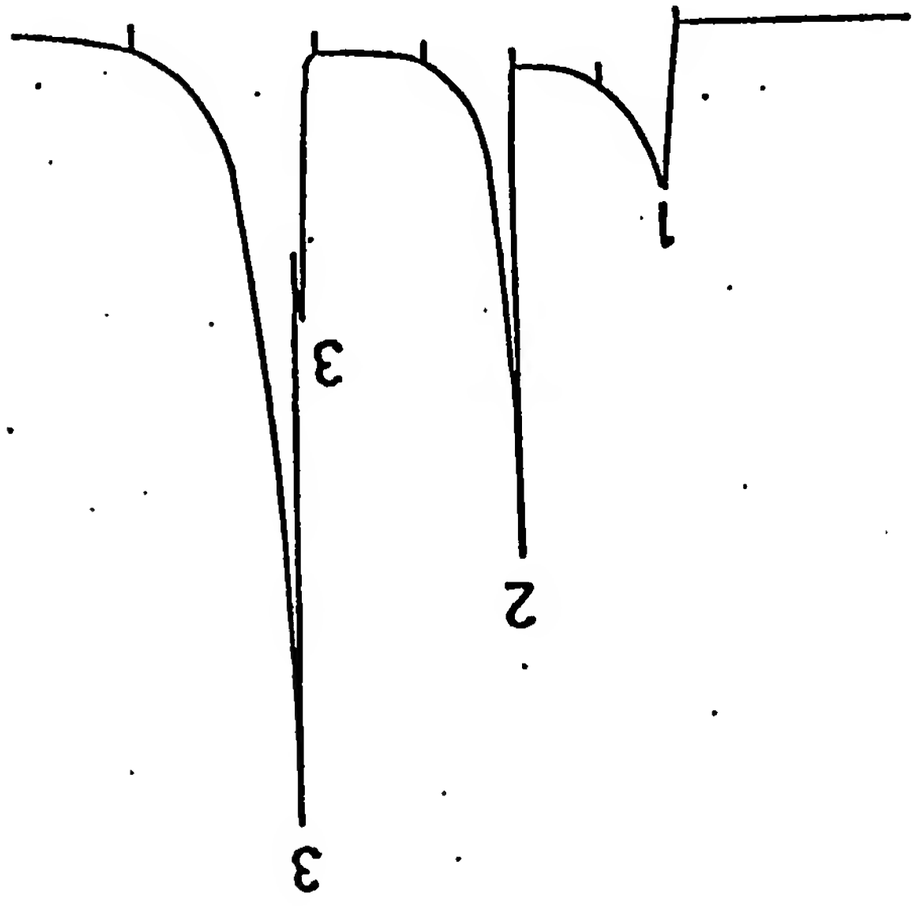


Fig. 2B



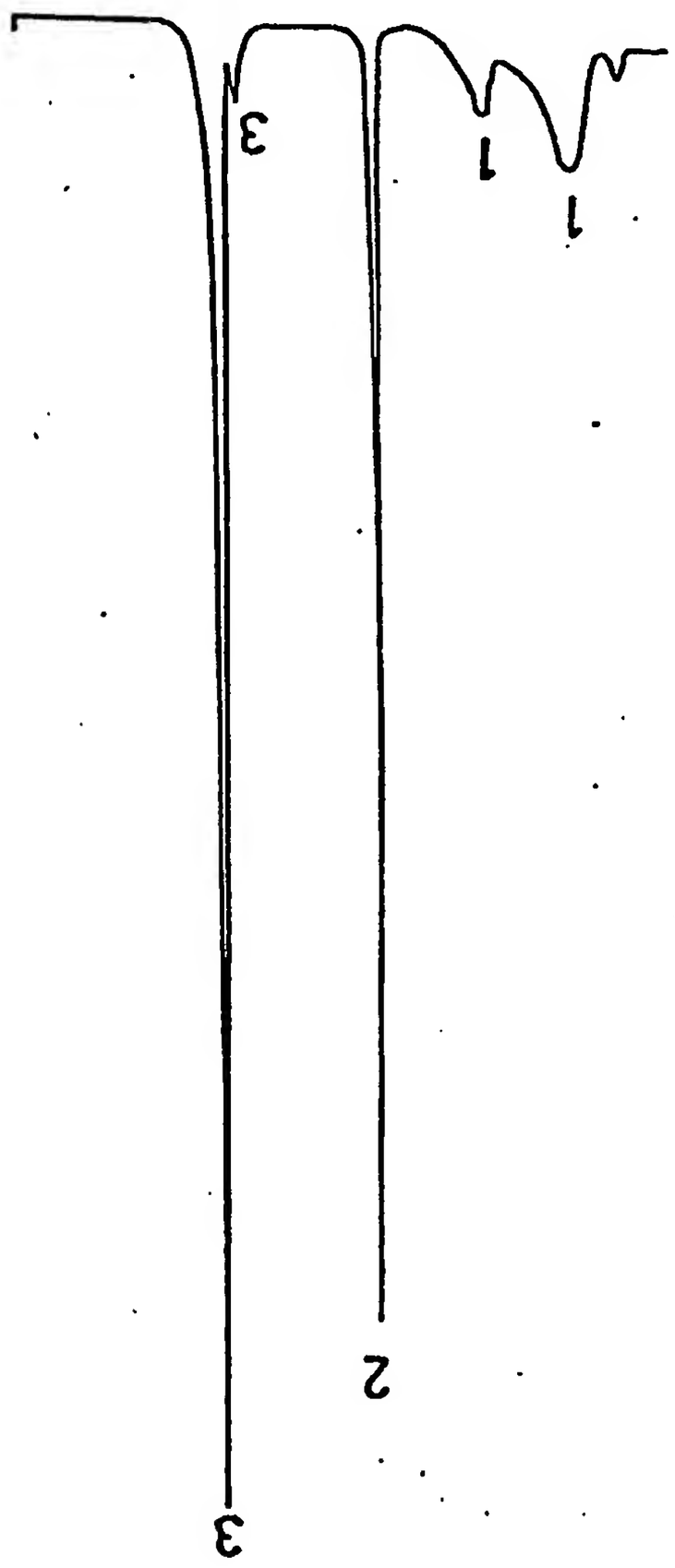


Fig. 3A

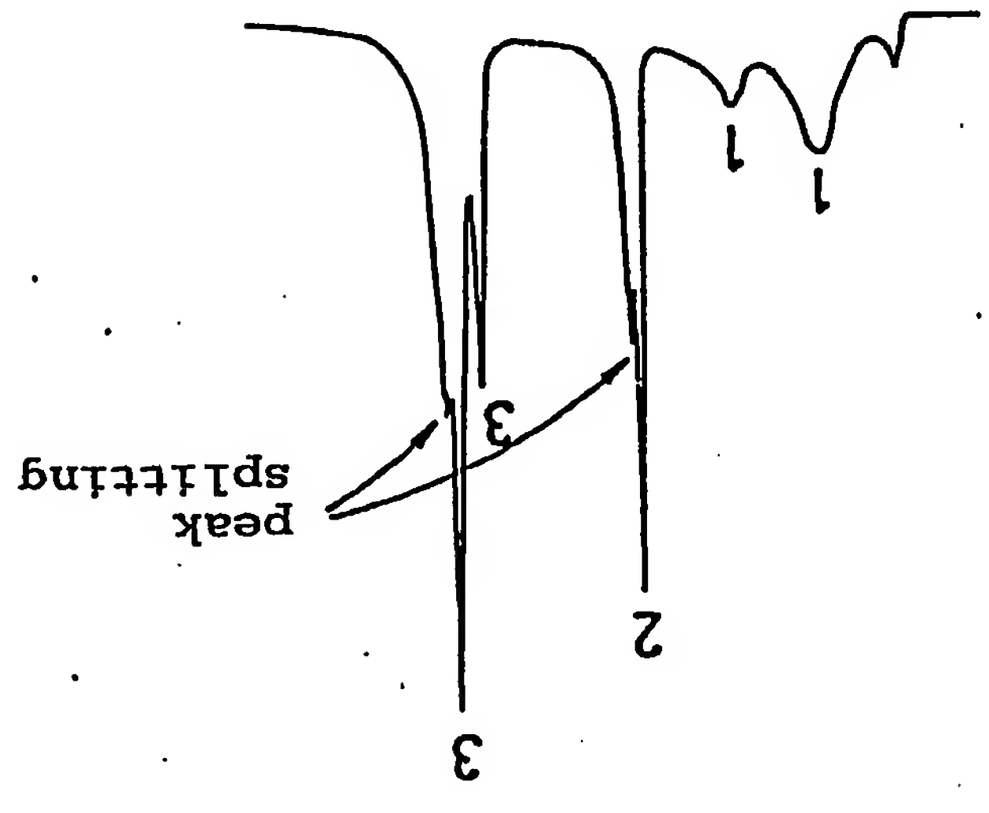


Fig. 3B

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 88 12 0728

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
P,A	EP-A-0 274 608 (KOKEN CO., LTD) * Column 1, lines 13-55; column 5, line 35 - column 6, line 26; claims 1-6 * ---	1,2,5,8,9	B 01 J 20/04 B 01 D 15/08 G 01 N 30/48 B 01 J 20/32
P,A	DE-A-3 722 102 (ASAHI KOGAKU KOGYO K.K.) * Column 1, line 29 - column 2, line 48; column 3, lines 3-1; example 1 * ---	1,2,5,8-10	
A	EP-A-0 217 614 (ASAHI KOGAKU KOGYO K.K.) * Page 1, line 6 - page 2, line 10; claim 2 * ---	1,2	
D,A	JOURNAL OF LIQUID CHROMATOGRAPHY, vol. 9, no. 16, 1986, pages 3543-3557, Marcel Dekker, Inc.; T. KADOYA et al.: "A new spherical hydroxyapatite for high performance liquid chromatography of proteins" * Pages 3543-3550 * ---	1,2,8,9,10	
A	CHEMICAL ABSTRACTS, vol. 90, 1979, page 57, abstract no. 97707e, Columbus, Ohio, US; F.D. BABCOCK et al.: "The reaction of stannous fluoride and hydroxyapatite", & J. DENT. RES. 1978, 57(9-10), 933-8 * Abstract * -----	6	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

B 01 J
B 01 D
G 01 N
C 01 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	13-01-1989	HILGENGA K.J.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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D : document cited in the application
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